The Future of Mine Planning Software – New Tools and Innovations

I.K. Kapageridis
Department of Geotechnology and Environmental Engineering, School of Technological Applications, Technological Education Institute of West Macedonia, Kozani, Greece

ABSTRACT: Modern mine planning software plays a crucial role in the operation of many of the world's mining operations and projects. Mine planning software provides the mining industry with a fast, accurate, cost effective and efficient tool in order to manage their business interests worldwide. Every aspect of the mining industry is today using some form of mine planning software. From exploration to rehabilitation, the use of software is becoming more and more widespread.

Mine planning software companies are constantly under pressure to evolve products to meet new challenges and solve new problems. Development of software is a result of both programming foresight and reaction to industry demands. Without mining industry feedback, many of the products now available would probably not have been developed. Mining software is an extremely competitive market which constantly drives the levels of development to new heights. This paper discusses some of the most important new tools and technologies incorporated in modern mine planning software and presents potential areas of improvement and further development.

1 INTRODUCTION

1.1 Mine Planning Software – A Historical Review

Mine planning and design software packages have been around for some time. Application of these packages has greatly improved the quality of designs as well as the overall economics throughout the mining process (Kaiser, et al, 2002).

The evolution of mine planning software started towards the late 70's across the world with a clear focus in operative gold mines where it was crucial to avoid any wasteful mining. Many of the current packages were initiated by existing mining companies or were off-loaded to universities as research projects (Ray, 2000). Competitive market pressures ensured that 3rd party software maintained a clear technological and functional advantage over in-house systems. Most major mining groups have abandoned in-house development in favor of commercial software.

In the last couple of decades, an increasing number of companies, engaged in the extraction of minerals throughout the world, have embraced the use of modern mine planning software. A great deal of historical information and data has been fed to such software to build large databases and models in existing mines. The first direct benefit was simply the use of largely unutilized information, and the validation of data that has been used in the past.

The 3D modeling capabilities of mine planning software became extremely important in assessing the environmental impact of new developments.

1.2 Modern Packages

There are a number of software products on the market today covering a large range of capabilities. Many packages are aimed at one particular market, such as database management and surveying. Others concentrate on CAD functionality. However, over the past couple of decades, a number of software packages have evolved to carry out most of the functionality required on an operation or project. The standard functionality carried out by these packages includes:

- Visualisation
- Modelling
- Database Management
- Reserve Calculation
- Mine Design
- Mine Planning

The development of mine planning software has gone through many changes in hardware compatibility, software tools and users expectations. These changes have impacted on management decisions as to the most cost effective approach to providing the users the applications they need. The major objective remained the same throughout this development: to provide users with tools that allow quick and accurate management and assessment of the value and risk associated with the exploration, feasibility and production of mineral resources.

With the increasing range and sophistication of the applications, the development and management of the software requires a greater level of co-ordination than the simpler non-integrated systems of some decades ago. Professional development of the software by dedicated teams of software engineers is essential to the production of software that satisfies users' expectations.

2 STRUCTURE OF MINE PLANNING SOFTWARE

2.1 Modularity

It is a common trend in most of the advanced mine planning software packages to have a modular structure. Usually there is a core program that controls other modules and enables communication of information and data between them. In some cases, this core program also incorporates the graphical environment.

Several modules are normally available, each with specialized functionality. Such modules can include:

- Samples database editor,
- Geological interpretation and modeling,
- Statistics and geostatistics
- Grid modeling editor
- Block modeling editor
- Reserving module
- Open pit design
- Underground design
- Open pit optimizer
- Production Scheduler
- Production Schedule Optimizer
- Plotting utility

Other more specialized modules can include groundwater and geotechnical modeling, surveying, and ventilation. This architecture provides a range of functionality including:

- A powerful, intuitive and interactive user interface, which minimizes user requirements to understand the workings of the computer and maximizes user ability to get close to their data and the models produced.
- A full range of sophisticated estimation and modeling algorithms for geological interpretation.
- A wide variety of mine design tools that generate the layout of the pit, analyze the economic limits, analyze slope conditions, plan ventilation requirements etc.
- Operational controls and monitoring systems are linked to design steps for areas such as survey, grade control, slope monitoring, truck dispatch etc.

2.2 Graphical Environments

A very important part of today's mine planning software, the graphical environment controls all aspects of visualization and graphical editing and analysis of data. Information from various sources such as samples databases, vector data (strings), block models, etc. are visualized in 3D within the graphical environment. Most of the on-screen interaction with the user is provided through this environment and for this reason most of the user friendliness of the entire package is defined here.

Any weakness of the graphical environment can render a very advanced mine planning package almost useless in the hands of an inexperienced user. Conversely, a powerful graphical environment can help an inexperienced user be more productive and significantly decrease the time required to build the necessary skills and expertise in computer aided mine planning.

Communication of visual information is always the most successful way to interact with other professionals and this adds to the significance of the graphical environment. Inherent complexities of three-dimensional data can be viewed with a true sense of depth and spatial relationship.

Most of today's mine planning software is based on well established visual technologies such as OpenGL (SGI), DirectX (Microsoft) or Java (Sun). The graphical environments benefit from the development of these technologies and become more stable and user friendly.

2.3 File Structures and Data Exchange

In the minerals industries, data comes from many different sources each of a distinct nature, such as drill logs, assay data, survey data, production statistics or real time equipment locations. Somewhere in its useful life data will be transferred between computer systems, even if it is only across an office, but commonly between two different software packages. The time wasted undertaking simple data transfer operations can be staggering (Jonkman and Savage, 1989). The few attempts made to create data transfer standards failed to gain universal acceptance and utlization (Hunter and Muller, 1990).

The use of AutoCAD (Autodesk Inc.) has become so widespread world-wide for architectural and surveying applications that the AutoCAD Drawing Exchange Format (DXF) has become the standard for 2D and 3D data exchange. Unfortunately, the DXF format itself is anything but standard and is constantly evolving, thus becoming a development issue for most of today's mine planning software.

2.4 Model Structures

There is a number of existing model structures used in mine planning software, such as grid and block models, triangulations (open and closed), and vector based models usually in the form of strings. The basic assumptions made by these models remained constant throughout the years of development. What changed is their flexibility and adjustability to more complex and realistic geological and extraction scenarios.

Grid models have evolved from simple arrays of nodes to complex structures that contain complex masking, faulting and other geometrical alterations. Block models, in particular, have become extremely large with sub-blocking capabilities that can match any geologist's desire for detail in following geological structures in three dimensions. The number of variables contained in the blocks also keeps increasing.

Triangulation models remained the same in their structure. However, major progress has been made in the way these models are visualized. Many of the advanced visual effects existing in Virtual Reality environments have found their way into modern mine planning software.

2.5 Algorithms

A modern mine planning package can contain an extremely large number of different algorithms providing the basis for most of its functionality. From geostatistics to pit optimization and from triangulation model editing to mine reserves calculations, the integrated algorithms bring to the users a range of options that define the levels of automation, functionality and user friendliness. Generally, the presence of certain algorithms and their sophistication can control the time required to achieve a certain modeling step or to edit an existing model. All this is hidden behind the GUI and users commonly take for granted what required years of research and money in the making.

Some of the advanced triangulation modeling and CAD algorithms that can be found in today's mine planning software are practically non-existent even in advanced VR modeling packages. The increased complexity of the entities modeled in the minerals industry is what drives most of the algorithm development. Clearly, modeling a car or a building is not as complex as trying to model a faulted orebody or a complex open pit with multiple ramps. The financial and safety consequences of the modeling process in the mine planning case can also be much more severe, adding to the drive for better and more sophisticated algorithms.

2.6 User Interface and Interactivity

Effective user interfaces reduce the amount of training required for a new user, however there will always be a significant training or learning overhead with all mine planning software packages. Computers often bring more effective working methods but they also bring change, and this requires careful management.

Much progress has been made in the area of user interfaces for office computing, as can be evidenced by the success of the WIMP (windows, icons, mouse, pull-down menus) style of interface but there is still a long way to go before we reach optimum human-computer interaction.

Users of mine planning software come from different fields and have very different perceptions as to how computers work (or should work) and this is why user interfaces must be adaptive and customizable. Serious efforts have been made in the last few years but there is still a lot to be done. As an indication of what is available to users regarding user interface customization we mention the following available functions that can be found in some of the most sophisticated mine planning packages:

- Customized toolbars: users can create new toolbars combining existing functionality that they use more frequently. This can also include extended functionality provided through scripts. Custom icons can be chosen and used to represent functionality through scripts.
- Context menus: different options that depend on the object/model that is being edited can be chosen to be accessed through simple mouse or keyboard keys.
- Customized GUI layout: users can change the position of toolbars, the size and position of the various windows.
- Customized GUI behavior: users can change the way the GUI operates. For example, in VULCAN following a certain operation, the GUI can open the same pull-down menu that was used to access the particular function.
- History menu options: users can access using the mouse or a special toolbar a certain number of the last menu options that they used. This is very useful when repeating similar modeling steps.

In addition to this specialized customization functionality, most of the functionality available through the hosting operating system/GUI (Microsoft Windows for example) is available to the user of a mine planning package.

3 NEW TOOLS FOR OLD PROBLEMS

The progress made by mine planning software in the recent years is evident in several areas of software development and operation. The most important areas of development are highlighted in the following paragraphs.

3.1 User/Software Interaction

It is essential that the user is able to interact with software easily and effectively. Modern software packages encourage users to customize their GUI (Graphical User Interface) to contain the options that are used most frequently. The various graphical environments give the user the visual capabilities to work with the data. True 3D graphics editors available in some of the more advanced packages such as VULCAN from Maptek Pty Ltd provide the necessary CAD functionality as well as 3D visualization (Figure 1).

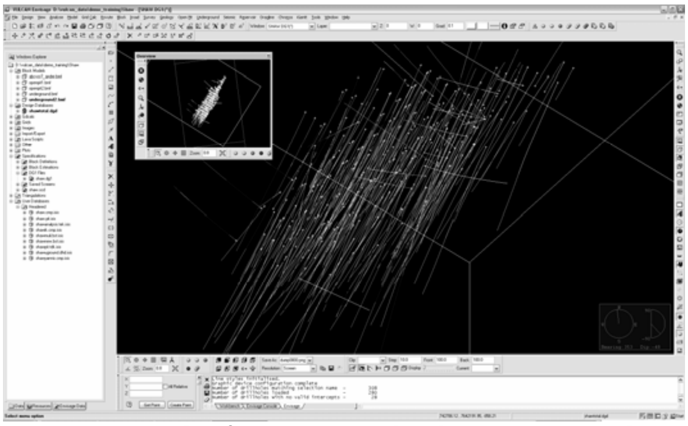

Figure 1: Example of a true 3D graphical environment and customizable GUI layout from VULCAN.

The interactive nature of the software can be taken one stage further by representing data in a dynamic setting. By dynamically “slicing” a block model, for example, the user can drag through from one block model extent to the other, on any axis. This particular function highlights the relationship between block model variables and triangulated workings, geological or orebody models. It also gives a dynamic look to the behavior of a block model, highlighting any problem in grade estimation or other variables.

The introduction of libraries, or locations for information on machinery used in mining operations, is becoming more widespread. By integrating real life machinery specifications, functions such as blast design can integrate real life data into the design process (Figure 2). Furthermore, by developing more complex algorithms, the behavior, advantages and limitations of machinery can be monitored, providing a more accurate design outcome. This is beneficial in many areas, for instance, in the calculation of toe spacings.

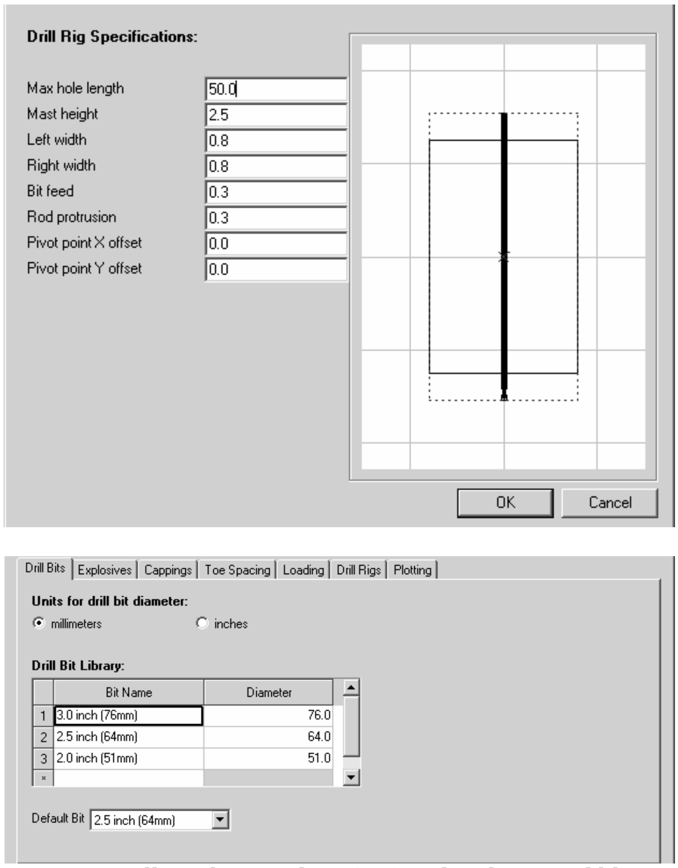

Figure 2: Drill rig design editor (top) and underground blasting specification panel (bottom) in VULCAN.

3.2 New Modeling Structures

The ever-increasing computational capacity, memory size and graphical capabilities of modern computers allow the enhancement of existing model structures as well as the development of new ones. Modelling on the basis of these new structures is possible to a level of detail never imagined before. The increase of random access memory (RAM) and the use of 64-bit file systems made room for block models with multi-billion blocks and triangulation models with billions of triangles. At the same time, the introduction of new graphics systems with plus-128Mb of specialised memory and ultra fast graphics processors made it possible to visualise such complex and large structures on high resolution display units at a low price. Some of the modern graphical environments have taken full advantage of these new developments and can handle models practically limitless in size and complexity.

A new model structure that is gaining popularity in the computer graphics industry is the tetrahedral model. Tetrahedral models can be considered an extension of the well known triangulation models in true 3D space. The basis of these models is not the triangle but the tetrahedron. Hence, tetrahedral models can be used to model structures not only by their external surface (as solid triangulations do) but within their volume (Jones and McGee, 2003). In VULCAN, the *Tetra Modelling* module utilises the tetrahedral model to perform structural analysis (variography) and grade estimation in structurally deformed ore bodies (Figure 3).

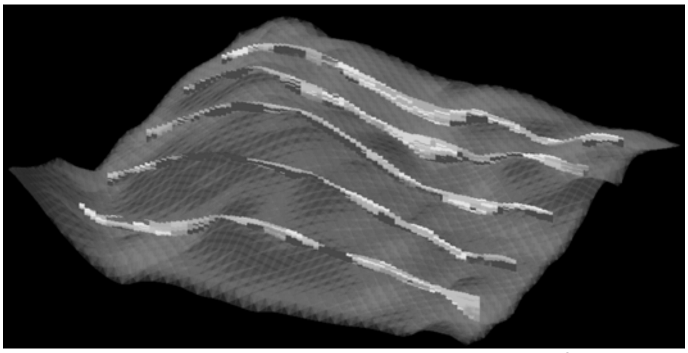

Figure 3: Grade estimation on a block model basis following a tetrahedral model of the ore body deformation. (Screenshot from VULCAN)

As mentioned above, the size of block models being created depends on the capabilities of both the hardware and the software design. The capabilities of modern hardware continue to expand at a large rate. Therefore, mining software must take advantage of this continual advance to push the limits and extents of modeling capabilities. This also applies to database functionality, allowing larger and more complex databases to be created and utilized at ever faster speeds and accuracy.

3.3 Extending Functionality through Scripting

Several scripting languages have been developed in the computer industry enabling advanced users to automate repetitive tasks and software producers to rapidly respond to new functionality demands. Perl, Tcl and Python are the most common examples of scripting languages adopted by today’s mining software. These scripting languages are usually extended to include more specialized functionality and give users access to the various file types and model structures available with the mine planning software. A very good example is VULCAN software’s Lava scripting language - an extension of the very well established Perl language. Lava enables the user to construct simple to very advanced programs that build upon the existing functionality of VULCAN. The user can access all data and model structures through a Lava script to retrieve information and perform further analysis and modeling in a more automated way. Lava scripts can be fully integrated with the existing user interface through toolbars. They can also extend the user interface with new panels for user input and control.

Customization of mine planning solutions can also help professionals from sectors for which the software was not originally designed, such as industrial minerals (Hack, 2003). Software developers have recognized scripting as a way to reach unexplored market areas.

3.4 Integration with GIS and Other Software

GIS (Geographic Information Systems) is having more and more influence on working procedures. Data sharing between professionals from various departments is always a key factor to the success of mining operations. This has lead to several advances that allow easier exchange of data between GIS and mine planning software (Elroi and Price, 1998).

A common scenario in many projects is the combined use of GIS and mining software. By providing an interface for leading GIS programs (such as ESRI’s ArcView), modern software packages enable the importing and exporting of GIS formats (for example, shape files or TINs). The advantage is that registered images can be brought into the mine planning software environment (such as geological maps) and integrated further with other data being used.

Another trend of today’s mine planning packages is the ability to communicate data and reports from database systems, design structures and models with other specialised or general software packages in a generic file format. Character Separated Variables (csv) files are becoming the norm for most packages. This format is very easy to import and export using the most common spreadsheet and database software packages or even simple text editors.

3.5 Integrated Simulation Capabilities

Mine planning systems are becoming increasingly dynamic in their modelling and visualisation processes. A number of visual aids allow the visualisation and analysis of mine designs and other data through time. We can effectively simulate the operation of a dragline, cast blasting, bulldozing, truck & shovel operations and any other kind of material movement, to develop a series of optimised range diagrams. These diagrams, combined in 3D and visualised at appropriate time intervals, give a very a clear picture of the extraction process (Figure 4).

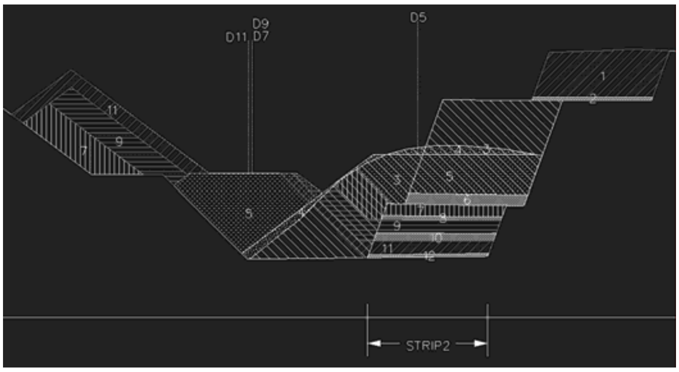

Figure 4: Range diagrams of dragline operation in VULCAN.

An exhaustive suite of tools is provided for moving blocks in a wide variety of ways, allowing the user to work in a fully interactive design environment. Complete, parametric control of all functional equipment dimensions provides a powerful, graphical tool for analyzing equipment capabilities and limitations. Average equipment cycles and swing angles are also calculated. Different swell factors and repose angles can be applied to different material types moved by the different equipment.

Formatted reports can be generated on blocks and operations, with totals and weighted averages tallied. Reporting in CSV format enables quick and easy importation into spreadsheet packages, allowing scope for additional analysis and scheduling, if required.

4 FUTURE TRENDS

Mining software is an extremely competitive market which constantly drives the levels of development to new heights. Not only must software companies react to the demands of the end user, but increasing competition between software companies generates products of consistently high quality and functionality. In this highly competitive market, modern software packages continue to develop functionality not found in other software packages.

Mining software can only continue to develop with the support and drive of the users in the mining industry. Mining companies should consider software packages as an investment, designed to help an operation in a number of different ways. All too often, cost is the primary consideration for companies when buying software. Cost should be balanced with *cost effectiveness* and an understanding of the value of the functionality that these packages offer (Lee, 2004). This type of investment not only aids the ongoing viability of operations and projects, but provides unique skills to the workforce. These skills will be more and more in demand as time goes on and to have personnel trained in this particular area is itself an investment in the people that make a mining company successful.

Looking to the future, the mining industry will become increasingly reliant on software. As deposits become more marginal, new features and procedures will need to be developed to make these marginal deposits economic. To do that, software must provide platforms that are cost effective and extremely efficient. Already, remarkable achievements have been made in a short space of time. Large datasets will continue to get larger, calculation times will continue to take less time to complete and designs will become increasingly interactive.

As the industry continues to develop and new techniques and procedures become apparent, mining software will be at the technological forefront to provide the industry with the tools necessary to meet these demands.

4.1 Advances in Computer Hardware and Operating Systems

Computer hardware is developing at a much higher rate than software. More powerful processors, faster data buses, faster and larger hard disks, faster and more sophisticated graphics systems enable us to do mine planning operations faster more accurate and considering many more controlling factors than before. What used to be extreme in geological modeling and mine design ten years ago is today common practice. Triangulations with hundreds of thousands of triangle faces, block models with millions of blocks, and pit optimization based on such extremely detailed block models is today a reality. The cost of the necessary hardware is not an issue anymore allowing smaller mining companies to have well organized IT departments.

Software development tools are more standardized today allowing developers to produce software of high quality and compatibility for the popular operating system platforms. This aspect of the development process will continue to improve with the release of better and more sophisticated development tools that will take advantage of the new hardware developments.

4.2 Software Integration

Neither the traditional piecemeal approach to having isolated pockets of uncooperative automation, nor the all-encompassing, high-cost, company-wide system that in many cases fails to deliver the promised product before being overtaken by the next major advance in hardware, are likely to achieve the desired result. Modern mine planning software must remain focused on the part of functionality that is truly required and not extend in areas that do not add to the value of the package and are already covered by well established specialized packages.

On the other hand, integrating functionality that is directly linked to the mine planning process, such as production scheduling and pit optimization, can be very beneficial as it will increase productivity levels and allow easier and faster analysis of different operational scenarios. In any case, integration must not lead to re-inventing the wheel as is very commonly happening in software development. In order to avoid this, better developed and maintained interfacing between applications must be considered.

4.3 Use of the Internet

The internet is a place where mine planning software can expand in many different ways. Currently it is being used for remote software licensing, data sharing and communication, troubleshooting and technical support between software providers and end-users, and distance learning. Software updates and demonstrations as well as other information are provided by various vendors to registered users of their software.

As the connection bandwidth is constantly increasing at the various mining sites where software is used, a number of new possibilities appear for extending software functionality and interaction between users and vendors. Distributed computing and other network based technologies will be incorporated in the more advanced mine planning packages.

5 CONCLUSIONS

The complexity of mine planning software will continue to increase with the requirements of problems that need solving. Integration of different software applications and data transfer between them continues to be vital to the efficiency of such systems.

The increase in the volume of data through modern exploration techniques and real-time monitoring systems requires that computers must be used to a large extent at all stages of the mining process. The data processing and analysis cycle may need many iterations if the mining company is to cope successfully with the changes in unforeseen geological conditions, changes in planning and environmental controls, and changes in the commodity price during the life of a mine. Those companies that achieve effective integration of computer systems are those that are most likely to cope with these changes and remain competitive.

Mine planning software, on the other hand, must continue to develop and adapt in form and functionality to satisfy current requirements and provide new methods for solving existing problems. A closer relationship between end-users and software developers will help achieve this target and ensure the future of mine planning software.

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